14.E: Oxidation-Reduction Reaction (Exercises)

Exercises (Oxidation-Reduction Reactions)

1. Is this reaction a redox reaction? Explain your answer. $2K(s) + Br_2(\ell) \rightarrow 2KBr(s)$

2. Is this reaction a redox reaction? Explain your answer. $2NaCl(aq) + Pb(NO_3)_2(aq) \rightarrow 2NaNO_3(aq) + PbCl_2(s)$

3. Which substance loses electrons and which substance gains electrons in this reaction? $2Mg(s) + O_2(g) \rightarrow 2MgO$

4. Which substance loses electrons and which substance gains electrons in this reaction? $16Fe(s) + 3S_8(s) \rightarrow 8Fe_2S_3(s)$

5. Which substance is oxidized and which substance is reduced in this reaction? $2Li(s) + O_2(g) \rightarrow Li_2O_2(s)$

6. Which substance is oxidized and which substance is reduced in this reaction? $2Fe(s) + 3I_2(s) \rightarrow 2FeI_3(s)$

7. What are two different definitions of oxidation?

8. What are two different definitions of reduction?

9. Assign oxidation numbers to the atoms in each substance.
   a. P_4
   b. SO_3
   c. SO_3^{2-}
   d. $Ca_3(PO_3)_2$

10. Assign oxidation numbers to the atoms in each substance.
    a. PCl_5
    b. $(NH_4)_2Se$
    c. Ag
    d. Li_2O_2

11. Assign oxidation numbers to the atoms in each substance.
    a. NO
    b. NO_2
    c. $CrCl_2$
    d. $CrCl_3$

12. Assign oxidation numbers to the atoms in each substance.
    a. NaH
    b. N_2O_3
    c. NO_2^-
    d. $CuNO_3$

13. Assign oxidation numbers to the atoms in each substance.
    a. CH_2O
    b. NH_3
    c. Rb_2SO_4
    d. $Zn(C_2H_3O_2)_2$

14. Assign oxidation numbers to the atoms in each substance.

a. C_6H_6
b. $B(OH)_3$
c. Li_2S
d. Au

15. Identify what is being oxidized and reduced in this redox reaction by assigning oxidation numbers to the atoms. $2NO + Cl_2 \rightarrow 2NOCl$

16. Identify what is being oxidized and reduced in this redox reaction by assigning oxidation numbers to the atoms. $Sr + SO_3 \rightarrow SrSO_3$

17. Identify what is being oxidized and reduced in this redox reaction by assigning oxidation numbers to the atoms. $2KrF_2 + 2H_2O \rightarrow 2Kr + 4HF + O_2$

18. Identify what is being oxidized and reduced in this redox reaction by assigning oxidation numbers to the atoms. $SO_3 + SCl_2 \rightarrow SOCl_2 + SO_2$

19. Identify what is being oxidized and reduced in this redox reaction by assigning oxidation numbers to the atoms. $2Rb + MgCl_2 \rightarrow 2RbCl + Mg$

20. Identify what is being oxidized and reduced in this redox reaction by assigning oxidation numbers to the atoms. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

Answers

1. yes because oxidation numbers are changing

3. lose: Mg; gain: O

5. oxidized: Li; reduced: O

7. increase in oxidation number; loss of electrons

9.

a. P: 0
b. S: +6; O: −2
c. S: +4; O: −2
d. Ca: +2; P: +3; O: −2

11.

a. N: +2; O: −2
b. N: +4; O: −2
c. Cr: +2; Cl: −1
d. Cr: +3; Cl: −1

13.

a. C: 0; H: +1; O: −2
b. N: −3; H: +1
c. Rb: +1; S: +6; O: −2
d. Zn: +2; C: 0; H: +1; O: −2

15. oxidized: N; reduced: Cl

17. oxidized: O; reduced: Kr

19.oxidized: Rb; reduced: Mg

Exercises (Balancing Redox Reactions)

1. Balance these redox reactions by inspection.
   a. $Na + F_2 \rightarrow NaF$
   b. $Al_2O_3 + H_2 \rightarrow Al + H_2O$

2. Balance these redox reactions by inspection.
   a. $Fe_2S_3 + O_2 \rightarrow Fe_2O_3 + S$
   b. $Cu_2O + H_2 \rightarrow Cu + H_2O$

3. Balance these redox reactions by inspection.
   a. $CH_4 + O_2 \rightarrow CO_2 + H_2O$
   b. $P_2O_5 + Cl_2 \rightarrow PCl_3 + O_2$

4. Balance these redox reactions by inspection.
   a. $PbCl_2 + FeCl_3 \rightarrow PbCl_4 + FeCl_2$
   b. $SO_2 + F_2 \rightarrow SF_4 + OF_2$

5. Balance these redox reactions by the half reaction method.
   a. $Ca + H^+ \rightarrow Ca^{2+} + H_2$
   b. $Sn^{2+} \rightarrow Sn + Sn^{4+}$ (Hint: both half reactions will start with the same reactant.)

6. Balance these redox reactions by the half reaction method.
   a. $Fe^{3+} + Sn^{2+} \rightarrow Fe + Sn^{4+}$
   b. $Pb^{2+} \rightarrow Pb + Pb^{4+}$ (Hint: both half reactions will start with the same reactant.)

7. Balance these redox reactions by the half reaction method.
   a. $Na + Hg_2Cl_2 \rightarrow NaCl + Hg$
   b. $Al_2O_3 + C \rightarrow Al + CO_2$

8. Balance these redox reactions by the half reaction method.
   a. $Br^- + I_2 \rightarrow I^- + Br_2$
   b. $CrCl_3 + F_2 \rightarrow CrF_3 + Cl_2$

9. Balance these redox reactions that occur in aqueous solution. Use whatever water-derived species is necessary; there may be more than one correct balanced equation.
   a. $Cu + NO_3^- \rightarrow Cu^{2+} + NO_2$
   b. $Fe + MnO_4^- \rightarrow Fe^{3+} + Mn$

10. Balance these redox reactions that occur in aqueous solution. Use whatever water-derived species is necessary; there may be more than one correct balanced equation.
    a. $CrO_3 + Ni^{2+} \rightarrow Cr^{3+} + Ni^{3+}$
    b. $OsO_4 + C_2H_4 \rightarrow Os + CO_2$

11. Balance these redox reactions that occur in aqueous solution. Use whatever water-derived species is necessary; there may be more than one correct balanced equation.
    a. $ClO^- + Ti^{2+} \rightarrow Ti^{4+} + Cl^-$
    b. $BrO_3^- + Ag \rightarrow Ag^+ + BrO_2$

12. Balance these redox reactions that occur in aqueous solution. Use whatever water-derived species is necessary; there may be more than one correct balanced equation.
    a. $H_2O_2 + NO \rightarrow N_2O_3 + H_2O$
    b. $VO_2^+ + NO \rightarrow V^{3+} + NO_2$

13. Explain why this chemical equation is not balanced and balance it if it can be balanced: $Cr^{2+} + Cl_2 \rightarrow Cr^{3+} + 2Cl^-$

14. Explain why this equation is not balanced and balance it if it can be balanced: $O_2 + 2H_2O + Br_2 \rightarrow 4OH^- + 2Br^-$

Answers

1.
    a. $2Na + F_2 \rightarrow 2NaF$
    b. $Al_2O_3 + 3H_2 \rightarrow 2Al + 3H_2O$

3.
    a. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
    b. $2P_2O_5 + 6Cl_2 \rightarrow 4PCl_3 + 5O_2$

5.
    a. $Ca + 2H^+ \rightarrow Ca^{2+} + H_2$
    b. $2Sn^{2+} \rightarrow Sn + Sn^{4+}$

7.
    a. $2Na + Hg_2Cl_2 \rightarrow 2NaCl + 2Hg$
    b. $2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$

9.
    a. $4H^+ + Cu + 2NO_3^- \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$ in acidic solution; $2H_2O + Cu + 2NO_3^- \rightarrow Cu^{2+} + 2NO_2 + 4OH^-$ in basic solution
    b. $24H^+ + 3MnO_4^- + 7Fe \rightarrow 7Fe^{3+} + 3Mn + 12H_2O$ in acidic solution; $12H_2O + 3MnO_4^- + 7Fe \rightarrow 7Fe^{3+} + 3Mn + 24OH^-$ in basic solution

11.
    a. $2H^+ + ClO^- + Ti^{2+} \rightarrow Cl^- + H_2O + Ti^{4+}$ in acidic solution; $H_2O + ClO^- + Ti^{2+} \rightarrow Cl^- + Ti^{4+} + 2OH^-$ in basic solution
    b. $2H^+ + BrO_3^- + Ag \rightarrow BrO_2 + H_2O + Ag^+$ in acidic solution; $H_2O + BrO_3^- + Ag \rightarrow BrO_2 + Ag^+ + 2OH^-$ in basic solution

13. The charges are not properly balanced. The correct balanced equation is $2Cr^{2+} + Cl_2 \rightarrow 2Cr^{3+} + 2Cl^-$.

Exercises (Applications of Redox Reactions - Voltaic Cells)

1. Draw the voltaic cell represented by this reaction and label the cathode, the anode, the salt bridge, the oxidation half cell, the reduction half cell, the positive electrode, and the negative electrode. Use Fig. 14.4.1 as a guide. $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$

2. Draw the voltaic cell represented by this reaction and label the cathode, the anode, the salt bridge, the oxidation half cell, the reduction half cell, the positive electrode, and the negative electrode. Use Fig. 14.4.1 as a guide. $3Mg + 2Cr^{3+} \rightarrow 3Mg^{2+} + 2Cr$

3. What is the voltage of this half reaction? $2F^- \rightarrow F_2 + 2e^-$

4. What is the voltage of this half reaction? $Na \rightarrow Na^{+} + e^{-}$

5. What is the voltage of the voltaic cell in Exercise 1? Consult Table 14.4.1.

6. What is the voltage of the voltaic cell in Exercise 2? Consult Table 14.4.1.

7. Balance this redox reaction and determine its voltage. Is it spontaneous? $Li^{+} + Al \rightarrow Li + Al^{3+}$

8. Balance this redox reaction and determine its voltage. Is it spontaneous? $Pb^{2+} + Ni \rightarrow Pb + Ni^{2+}$

9. Balance this redox reaction and determine its voltage. Is it spontaneous? $Cu^{2+} + Ag + Cl^{-} \rightarrow Cu + AgCl$

10. Balance this redox reaction and determine its voltage. Is it spontaneous? $Mn^{2+} + Br_2 \rightarrow MnO_4^{-} + Br^{-}$

11. Which reaction represents the cathode reaction in Exercise 7? The anode reaction?

12. Which reaction represents the cathode reaction in Exercise 8? The anode reaction?

13. Which reaction represents the cathode reaction in Exercise 9? The anode reaction?

14. Which reaction represents the cathode reaction in Exercise 10? The anode reaction?

15. A voltaic cell is based on this reaction: $Ni + 2Au^{+} \rightarrow Ni^{2+} + 2Au$; If the voltage of the cell is 0.33 V, what is the standard reduction potential of the $Au^{+} + e^{-} \rightarrow Au$ half reaction?

16. A voltaic cell is based on this reaction: $3Pb + 2V^{3+} \rightarrow 3Pb^{2+} + 2V$; If the voltage of the cell is −0.72 V, what is the standard reduction potential of the $V^{3+} + 3e^{-} \rightarrow V$ half reaction?

17. What species is being oxidized and what species is being reduced in a dry cell?

18. What species is being oxidized and what species is being reduced in an alkaline battery?

19. What species is being oxidized and what species is being reduced in a silver oxide button battery?

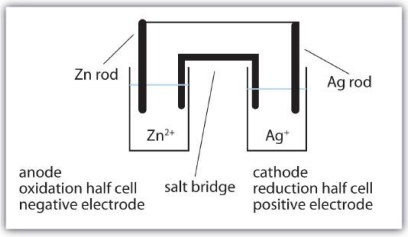
20. What species is being oxidized and what species is being reduced in a lead storage battery?

21. Based on the data in Table 14.4.1, what is the highest voltage battery you can construct?

22. Based on the data in Table 14.4.1, what is the lowest voltage battery you can construct? (This may be more challenging to answer than Exercise 21.)

Answers

1.



3. −2.87 V

5. 1.56 V

7. $3Li^+ + Al \rightarrow 3Li + Al^{3+}$; −1.39 V; not spontaneous
9. $Cu^{2+} + 2Ag + 2Cl^- \rightarrow Cu + 2AgCl$; 0.12 V; spontaneous
11. cathode reaction: $Li^+ + e^- \rightarrow Li$; anode reaction: $Al \rightarrow Al^{3+} + 3e^-$
13. cathode reaction: $Cu^{2+} + 2e^- \rightarrow Cu$; anode reaction: $Ag + Cl^- \rightarrow AgCl + e^-$
15. 0.08 V
17. oxidized: Zn; reduced: Mn
19. oxidized: Zn; reduced: Ag
21. 5.92 V from the reaction of F_2 and Li

Exercises (Electrolysis)

1. Define *electrolytic cell*.
2. How does the operation of an electrolytic cell differ from a voltaic cell?
3. List at least three elements that are produced by electrolysis.
4. Write the half reactions for the electrolysis of the elements listed in Exercise 3.
5. Based on Table 14.4.1, what voltage must be applied to an electrolytic cell to electroplate copper from Cu^{2+}?
6. Based on Table 14.4.1, what voltage must be applied to an electrolytic cell to electroplate aluminum from Al^{3+}?

Answers

1. an electrochemical cell in which charge is forced through and a nonspontaneous reaction occurs

3 any three of the following: Al, K, Li, Na, Cl_2, or Mg

5. 0.34 V

Additional Exercises

1. Oxidation was once defined as chemically adding oxygen to a substance. Use this reaction to argue that this definition is consistent with the modern definition of oxidation: $2Mg + O_2 \rightarrow 2MgO$
2. Reduction was once defined as chemically adding hydrogen to a substance. Use this reaction to argue that this definition is consistent with the modern definition of reduction: $C_2H_2 + 2H_2 \rightarrow C_2H_6$
3. Assign oxidation numbers to the atoms in each substance.
   a. Kr (krypton)
   b. krypton tetrafluoride (KrF_4)
   c. dioxygen difluoride (O_2F_2)
4. Assign oxidation numbers to the atoms in each substance.
   a. lithium hydride (LiH)
   b. potassium peroxide (K_2O_2)
   c. potassium fluoride (KF)
5. N atoms can have a wide range of oxidation numbers. Assign oxidation numbers for the N atom in each compound, all of which are known compounds.
   a. N_2O_5
   b. N_2O_4

c. NO_2
d. NO
e. N_2H_4
f. NH_3

6. Cr atoms can have a wide range of oxidation numbers. Assign oxidation numbers for the Cr atom in each compound, all of which are known compounds.
   a. Na_2CrO_4
   b. $Na_2Cr_2O_7$
   c. CrF_5
   d. $CrCl_3$
   e. $CrCl_2$

7. Balance this redox reaction by inspection: $S_8 + O_2 \rightarrow SO_2$

8. Balance this redox reaction by inspection: $C_{18}H_{38} + O_2 \rightarrow CO_2 + H_2O$

9. Balance this redox reaction by the half reaction method by assuming an acidic solution: $Cr_2O_7^{2-} + Fe \rightarrow Cr^{3+} + Fe^{3+}$

10. Balance the redox reaction in Exercise 9 by the half reaction method by assuming a basic solution.

11. The uranyl ion (UO_2^{2+}) is a fairly stable ion of uranium that requires strong reducers to reduce the oxidation number of uranium further. Balance this redox reaction using the half reaction method by assuming an acidic solution.$UO_2^{2+} + HN_3 \rightarrow U + N_2$

12. Balance the redox reaction in Exercise 11 by the half reaction method by assuming a basic solution.

13. Zinc metal can be dissolved by acid, which contains H^+ ions. Demonstrate that this is consistent with the fact that this reaction has a spontaneous voltage: $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$

14. Copper metal cannot be dissolved by acid, which contains H^+ ions. Demonstrate that this is consistent with the fact that this reaction has a nonspontaneous voltage: $Cu + 2H^+ \rightarrow Cu^{2+} + H_2$

15. A disproportionation reaction occurs when a single reactant is both oxidized and reduced. Balance and determine the voltage of this disproportionation reaction. Use the data in Table 14.4.1 - Standard Reduction Potentials of Half Reactions: $Cr^{2+} \rightarrow Cr + Cr^{3+}$

16. A disproportionation reaction occurs when a single reactant is both oxidized and reduced. Balance and determine the voltage of this disproportionation reaction. Use the data in Table 14.4.1 - Standard Reduction Potentials of Half Reactions: $Fe^{2+} \rightarrow Fe + Fe^{3+}$

17. What would be overall reaction for a fuel cell that uses CH_4 as the fuel?

18. What would be overall reaction for a fuel cell that uses gasoline (general formula C_8H_{18}) as the fuel?

19. When NaCl undergoes electrolysis, sodium appears at the cathode. Is the definition of cathode the same for an electrolytic cell as it is for a voltaic cell?

20. When NaCl undergoes electrolysis, chlorine appears at the anode. Is the definition of anode the same for an electrolytic cell as it is for a voltaic cell?

21. An award is being plated with pure gold before it is presented to a recipient. If the area of the award is 55.0 cm^2 and will be plated with 3.00 µm of Au, what mass of Au will be plated on the award? The density of Au is 19.3 g/cm^3.

22. The unit of electrical charge is called the coulomb (C). It takes 96,500 coulombs of charge to reduce 27.0 g of Al from Al^{3+} to Al metal. At 1,040 cm^3, how many coulombs of charge were needed to reduce the aluminum in the cap of the Washington monument, assuming the cap is pure Al? The density of Al is 2.70 g/cm^3.

Answers

1. As oxygen is added to magnesium, it is being oxidized. In modern terms, the Mg atoms are losing electrons and being oxidized, while the electrons are going to the O atoms.

3.

a. Kr: 0
b. Kr: +4; F: −1
c. O: +1; F: −1

5.

a. +5
b. +4
c. +4
d. +2
e. −2
f. −3

7. $S_8 + 8O_2 \rightarrow 8SO_2$

9. $14H^+ + Cr_2O_7^{2-} + 2Fe \rightarrow 2Cr^{3+} + 7H_2O + 2Fe^{3+}$

11. $6HN_3 + UO_2^{2+} \rightarrow U + 2H_2O + 9N_2 + 2H^+$

13. The voltage of the reaction is +0.76 V, which implies a spontaneous reaction.

15. $3Cr^{2+} \rightarrow Cr + 2Cr^{3+}$; −0.50 V

17. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

19. yes because reduction occurs at the cathode

21. 0.318 g

a.